Resource Sharing Challenge for Micro Operator Pattern in 5G SDN / NFV Network

[1]Skulysh Mariia, [1]Globa Larysa, [2]Siemens Eduard
[1]*Institute Institute of Telecommunication Systems Igor Sikorsky Kyiv Politechnic InstituteKyiv, Ukraine*
mskulysh@gmail.com, lgloba@its.kpi.ua
[2]*Anhalt University of Applied Sciences, Germany*
eduard.siemens@hs-anhalt.de

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Abstract: To expand the capabilities of their networks, large operators turn to smaller operators for help, which allows servin g more users. This is possible because software-defined network technologies and virtualization of network functions are used. However, the distribution of subscriber flows between the micro-operators networks problem arises. Micro-operator networks have limited technical resources. The network resources consumed by the services are unevenly in time distributed. There are situations when the network resources of the operator are not enough. At the same time, service consumers want to receive services at a given level of QoS. For dynamic control of the sufficiency of micro-operator resources, the article proposes the dynamic flow control method. The method algorithm include the stages: the flows and node resources use monitoring, the optimal node load calculation, prediction of exceeding the permissible load value, and automatic live migration. The modelling proposed algorithm results showed that there are no more overloads of the micro operator networks. The level of service delays decreased by 5%.

1 INTRODUCTION

A significant part of the new operators prefers to cooperate with small micro-telecommunication networks that cover the interior after the onset of the 5G era. Since these operators can provide various networks such as 3G, 4G, 5G and even Wi-Fi [1,2].

Up-to-day technology use more and more Network Function [7] that is a functional unit within a network infrastructure that has clearly defined external interfaces and well-defined functional behaviour. In practice, a network function is today a network node or physical device.

Thanks to new SDN/NFV technologies the Internet provider can deploy its networks more flexibly and dynamically [3,8]. The Internet provider can so provide localized services e.g. in public buildings. This opportunity not only changes the mechanism of network deployment but also fosters micro operator's creation [4-6]. The following factors contribute to the creation of a Mobile Virtual Network Operator:

- lack of spectrum resources
- efficient usage of bandwidth
- the scale of the mobile communications market
- the ability of consumers to diversify services,

which, in turn, lead to more diverse applications and services in the telecommunications market. Mobile Virtual Network Operator can be applied to any wireless service provider that provide wireless services to consumers and do not have its own wireless network infrastructure. It provides completely new opportunities for development in a mature mobile communications market and stimulates the telecommunications market to move towards service-oriented competition.

Figure 1 presents the Micro Operator network architecture [8]. The micro-operator itself is small in scale and limited in telecommunication (network, hardware and others) and computation (servers, storages and so) resources to provide the necessary services to a certain number of users. The radius of access for mobile devices is limited by the scope of a particular local network (small cells) service which

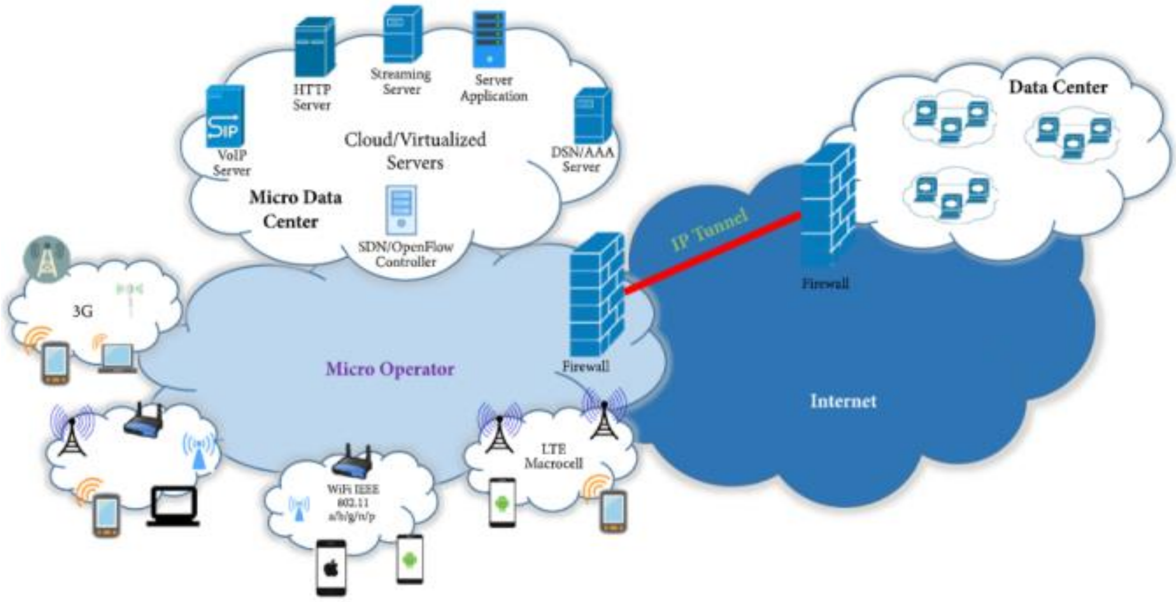

Figure 1: Micro operator network architecture.

depends on the corresponding available network resources. Institutions such as hospitals, schools, large conferences, sports centres, shopping centres, hypermarkets and factories can use local network services to meet the needs of users in all types of applications.

Regionalization is the nature of the service, which allows it to provide under conditions with limited hardware infrastructure and resources various regional services in different regions allowing mobile users to access the services in other regions. In addition to reduce the consumption of bandwidth resources by providing neighboring network services this type of service localization can also transfer applications, data and computing services from nodes in the data center to the cloud to border nodes in a logical LANs which must be processed and implemented. The computing environment organized by the Fog computing technology reduces network latency and meets 5G requirements.

2. THE NETWORK RESOURCES ALLOCATION TASK

2.1 Reference and Related Work

The Internet of Things (IoT) is supposed to become the killer application of 5G networks and to foster new communications markets. The result will be the formation of different new application scenarios and more diversified network requirements. However, with regard to telecommunications, despite the fact that there is now a globally agreed IoT requirement, built with 5G characters such as speed transfer, capacity, coverage and security, there is still room for the 5G business model to improve. The 5G mobile broadband network focuses on small cells/base stations, enhances internal coverage, provides faster user maintenance and reduces network delays, creating a serious problem for telecom operators. In addition, the the emergence of MVNO has brought new opportunities for development of mobile operators who have not yet received frequency licenses for mobile communications. MVNOs use the spectrum and network of mobile operators to provide individual mobile services, corporate virtual private networks for specific businesses or many other micro-markets where operators have not yet expanded their services to less-performing or regional emerging markets. There is a tendency for regionalization between small cellular/base stations, and regional services do not handle the public network, the network of industrial applications of the network. The Micro Operator business is a new network business model that began to evolve [8]. The manual provides a mechanism for transferring access to a common spectrum of micro-operators and shared single-mode physical network infrastructure using virtual technology to fully utilize a valuable bandwidth resource.

2.2 Micro Operator Design Model in 5G networks and the network selection step

The interaction between SDN and NFV allows the introduction of a system design model for 5G network infrastructure[10-14]. Flexibility is ensured through a modular approach. Separate problems are solved in the appropriate modules, which are connected as needed. Therefore, we have the flexibility to manage the network in which the deployed networks of micro operators. The operator can switch to using technology cuts network virtualization and networks, as mentioned above, the flexibility to split a physical network into several independent networks and isolated User Interface under different scenarios.

Thus, the task is to organize the maintenance of independent slices within the existing information and telecommunication infrastructure. To ensure the maintenance of independent slices, the following features must be considered:

- it is required to provide each with sufficient amount of resources, both telecommunication and computing ones, for servicing virtualized network functions in order to provide service at a given quality level.
- it is necessary to take into account the nature of the load change in each slice for optimal allocation of resources between slices during the day.
- determine the conditions for the migration of slices in the telecommunications infrastructure, which will ensure the smooth operation of the system.

With regard to infrastructure design, this document uses technologies such as SDN and NFV base and combines network technology and tunnels to build the network infrastructure for microserveses. Infrastructure allows users to connect multiple IVS using tunneling technology and running fast network connection to effectively strengthen the relationship networks.

The design model is shown in Figure 2 [8], where the network threading technology implements the logical section of ND networks through OpenVirtex. The connection between the base network and Micro Operator network are performed by a tunnel constructed using the SDN (as a border gateway (BG). The Internet Data Center and the data center are developed using the ETSI-defined NFV infrastructure to save equipment investments. The mission of the SDN controller is to use OpenFlow to construct the path between the BG at the edge of the base network and the BG at the edge of the Micro Operator network. When the SDN controller begins to coordinate and concatenate between the network passages, the Micro Operator network can build a tunnel connection and a basic backbone network.

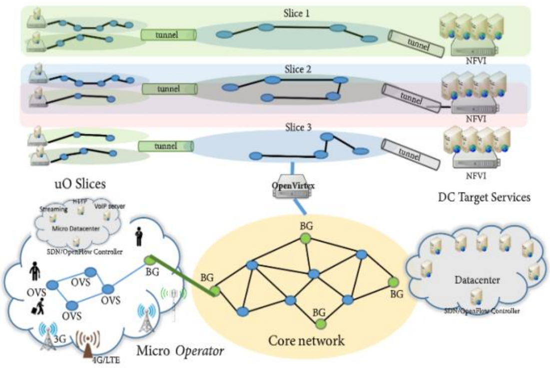

Figure 2: A Micro Operator(μO) design pattern with network slicing

The Micro Operator can continue to complete the virtual network construction using OpenVirtex virtual winding technology, which allows users to access data in the nearest micro datacenter. Users can also, through tunnels, connect to a cloud datacenter on the Internet to access the service from a specific application network. The proposed architecture combines threading and network tunneling to implement a communication model for Micro Operator and further integrates the bandwidth management technology that applies to the bandwidth application of Micro Operator network. This will increase the utilization of network resources and the efficiency of traffic flow and will lead to a better QoE experience for network users.

In response to the demand of Micro Operator's network resource distribution that allows users to gain access of nearby network resources, the paper [8] proposes network selection mechanism for a Micro Operator and uses decision tree theory to serve as the reference in determining the SDN traffic flows path. The proposed method disadvantage is that traffic will be distributed without taking into account the all network resources load..

The method shown in Fig. 3 application will allow to predict the moments micro operator network overload and to migrate the subscriber sessions bitween micro-operators network tunels in time, which will allow to provide conditionally infinite bandwidth micro-operators network.

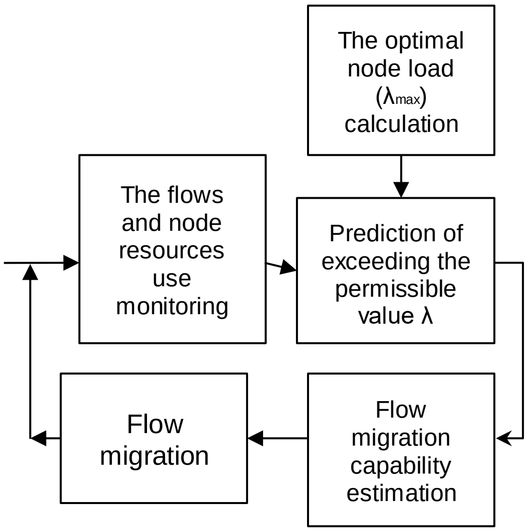

Figure 3: Dynamic Flow Control Algorithm

The "The flows and node resources use monitoring" block involves the accumulation the communication channels congestion information, and information about the resource use dynamics by each service.

For the edicion of the possibility of exceeding the permissible value λ (the admissible input stream intensity), the method proposed in [15] is used. The basic method idea is to formulate requirements for the average input load on the basis of ergodic distribution for the possible states of the system, which will allow to make the most efficient use of the available physical resources of servicing the incoming application flow.

For prediction of exceeding the permissible value λ we propose to use the method [7] consists of two stages: the calculation of the prediction interval based on the operation servicing node statistics and directly periodic forecasting of the load and the control of the sufficiency resources.

If periodic forecasting of the load showed that it overload is expected and the available slice resources are not enough to provide services at a given level, then the migration mechanism starts.

2.3. Method of Automatic Live Migration

It is necessary to provide automatic load balancing of physical resources of telecommunications nodes while avoiding overloading one node and an inefficient use of another one. The mechanism of this balancing is called "smart migration".

Formulation of the problem. The system shall provide:

- the migration process should be invisible to the services user;
- the migration process should be aimed at optimizing the telecommunication network state;
- when planning a migration, one shall assure that two channels (operative and backup) of one slice will not be located in the same physical telecommunications node, so it must support high availability;
- One of the important requirements for migration is the maximum time to complete it, as long migration time can negatively affect the state of the system;
- the system must provide protection against looping, that is, from the endless migration of the same slice;
- it shall provide protection against failures and work in a cluster mode, which is especially important for multiple migrations.

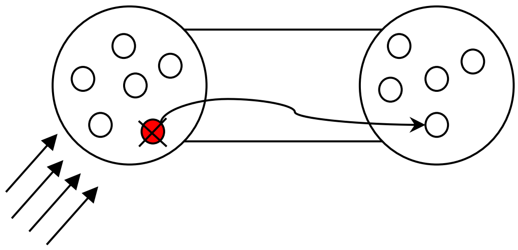

Figure 4: Flow migration between the neighboring micro-operator networks

Migration System Architecture. There is information about the statistics of the telecommunications nodes and the load that the slice creates on the telecommunications node. This data is periodically read and transformed into metrics that are stored in a specific repository. Thus, by accessing this repository it is possible to obtain information on the dynamics of resource consumption on a separate telecommunications node or slice at any time. information is also available on the number of resources that physical servers have.

The decision on the need for migration as well as on what and where the control unit should migrate. After selecting candidates for migration, they are placed in a distributed queue, which is processed by a special process. This process analyzes information on the number of items in the queue and, based on this information, selects the item to be migrated. The process of physical migration is synchronous without any discontinuities or returns, while there is a special mechanism that ensures that there are no errors and delays. The main task of the process is to ensure the selection of a candidate for migration and to move it to a certain telecommunications node in such a way as to optimize the state of the system. Thus, there is a multi-dimensional optimization problem. There are several algorithms for solving this problem.

Simple algorithm:

1. Looking for the most loaded node
2. The server selects the most optimal node in terms of the amount of resources consumed
3. Move the slice

This algorithm is easy to use, however, with large number of communication nodes, the algorithm is not yet optimal. For such cases, you need to use a more complex algorithm. Its essence is as follows. Special rules are defined that must be met by the optimal solution. There are strict rules that can't be violated under any circumstances and soft rules that can be neglected in some cases. In addition, the types of problem solutions are determined:

- possible solutions - solutions that are achieved in violation of strict rules (bad decisions);
- feasible solutions - decisions that do not violate hard conditions, but do not fulfill a part of soft ones;
- optimal solutions - solutions that fulfill both types of conditions;
- optimal solutions are the best solutions calculated in the shortest time.

To solve a problem using a complex algorithm, it is necessary to pre-define soft and hard constraints.

Hard restrictions:

1. The amount of resources of the target node must be sufficient to move the slice. In addition, redundancy resources must be provided.
2. Slice cannot migrate to its own physical node.
3. On the same physical node should not be located streams of the same slice. This condition ensures that the minimum amount of data is lost in the event of a system failure.

Soft restrictions:

1. Migrate the most loaded slice streams
2. The target physical node shall be the least loaded one

The main disadvantage of this algorithm is the lack of tools to account for trends in the rate of resource consumption by various slices. A study was conducted on the effectiveness of accounting for statistical data in the process of selecting a stream for migration, as well as a node to which the migration will be carried out.

In order to correctly select the node to which the migration will be performed, it is necessary to assess the trend of changes in the resource usage dynamics of the selected server while taking into account the load that the migrating slice stream will create.

To determine the moment of migration, it is necessary with a specified time interval to evaluate the current statistics of resource utilization, to build a statistical trend on the number of serviced requests. Based on the trend, an assessment is made of the likelihood that the maintenance of containers located on the node under study will exceed the allowable amount of resources, then the migration process will start. The method of assessing the adequacy of resources is presented in [10].

Thus, based on the current load statistics generated by the sum of the flows of the individual slices; estimates of the upper limit of the capacity of the telecommunications node will be decided on the need for migration.

3. THE SIMULATION RESULTS

The simulation was conducted in the Matlab environment. The initial model data thewere mobile telecom operator statistical data from the resources and services monitoring systemper day.

Table 1.

	The services distribution between micro operators is fixed	Dynamic Flow Control Algorithm
resource overload	10%	0%
number of service migrations	-	10
Service delays	8%	3%

Network resources were conditionally divided into separate micro operator network slices. The micro operator network resources were fixed. Services usege statistics by network subscribers was analyzed as follows:

1. Without balancing. The resource usege indicators of the micro operator's network by assigned subscribers group over the norm were estimated.
2. The number of subscribers assigned to the micro-operator changed according to the Dynamic Flow Control Algorithm..

The comparative analysis results are shown in Table 1. Thus, in order to avoid the micro operator network overloading, it is necessary to use the method of dynamic flow control, which includes the mechanisms of live flows migration and provides conditionally infinite service resources.

4. CONCLUSION

This document uses SDN and NFV technologies as the basis and combines network streaming and tunneling technologies to create a network infrastructure model for MSO using a smart migration mechanism. This model allows users of different MOs to connect using tunneling technology, and then implement a fast network connection to effectively improve network interaction, while balancing the load between all nodes of a given network. To meet the needs of the regional micro-operator service, this article proposes a DTBFR mechanism that uses decision tree theory as the basis for making SDN-based traffic decisions. As a distribution and control of the load on the nodes, we use the method of slices working together in the existing telecommunication foreign infrastructure, which ensures the automatic distribution of telecommunication and computing resources of the system depending on the load and allows solving the problem of peak loads and idle resources. This method of automatic load balancing of telecommunication nodes ("smart migration") does not allow overloading one node and downtime of another node. The functions used by the regional micro-operator service can effectively reduce the load on the datacenter on the Internet and accelerate the development of the regional computer service in the future 5G network. And the "smart migration" method will allow rational use of network resources.

REFERENCES

[1] A. Raschellà, F. Bouhafs, G. C. Deepak, and M. Mackay, "QoS aware radio access technology selection framework in heterogeneous networks using SDN," Journal of Communications and Networks, vol. 19, no. 6, pp. 577–586, 2017.

[2] M. Matinmikko, M. Latva-aho, P. Ahokangas, S. Yrjölä, and T. Koivumäki, "Micro operators to boost local service delivery in 5G," Wireless Personal Communications, vol. 95, no. 1, pp. 69–82, 2017.

[3] J. S. Walia, H. Hammainen, and M. Matinmikko, "5G Micro-operators for the future campus: A techno-economic study," in Proceedings of the 2017 Internet of Things - Business Models, Users, and Networks, pp. 1–8, Copenhagen, Denmark, November 2017.

[4] M. Matinmikko-Blue and M. Latva-aho, "Micro operators accelerating 5G deployment," in Proceedings of the 2017 IEEE International Conference on Industrial and Information Systems (ICIIS), pp. 1–5, Peradeniya, Sri Lanka, December 2017.

[5] P. Ahokangas, S. Moqaddamerad, and M. Matinmikko, "Future micro operators business models in 5G," The Business and Management Review, vol. 7, no. 5, pp. 143–149, 2016.

[6] P. Mach and Z. Becvar, "Mobile Edge Computing: A Survey on Architecture and Computation Offloading," IEEE Communications Surveys & Tutorials, vol. 19, no. 3, pp. 1628–1656, 2017

[7] Globa, L., Skulysh, M., Romanov, O., & Nesterenko, M. (2018, November). Quality Control for Mobile Communication Management Services in Hybrid Environment. In The International Conference on Information and Telecommunication Technologies and Radio Electronics (pp. 76-100). Springer, Cham.

[8] Skulysh, M. A., Romanov, O. I., Globa, L. S., & Husyeva, I. I. (2018, September). Managing the Process of Servicing Hybrid Telecommunications Services. Quality Control and Interaction Procedure of Service Subsystems. In International Multi-Conference on Advanced Computer Systems (pp. 244-256). Springer, Cham.

[9] Chia-Wei Tseng, Yu-Kai Huang, Fan-Hsun Tseng, Yao-Tsung Yang, Chien-Chang Liu, and Li-Der Chou, "Micro Operator Design Pattern in 5G SDN/NFV Network," Wireless Communications and Mobile Computing, vol. 2018, Article ID 3471610, 14 pages, 2018.

[10] Semenova, O., Semenov, A., & Voitsekhovska, O. (2019, July). Neuro-Fuzzy Controller for Handover Operation in 5G Heterogeneous Networks. In 2019 3rd International Conference on Advanced Information and Communications Technologies (AICT) (pp. 382-386). IEEE.

[11] Skulysh, M. (2017, September). The method of resources involvement scheduling based on the long-term statistics ensuring quality and performance parameters. In 2017 International Conference on Information and Telecommunication Technologies and Radio Electronics (UkrMiCo) (pp. 1-4). IEEE.

[12] M. Skulysh; O. Romanov. The structure of a mobile provider network with network functions virtualization. In: 2018 14th International Conference on Advanced Trends in Radioelecrtronics, Telecommunications and Computer Engineering (TCSET). IEEE, 2018. p. 1032-1034.

[13] Globa, L., Kurdecha, V., Ishchenko, I., Zakharchuk, A., & Kunieva, N. (2018, June). The intellectual IoT-system for monitoring the base station quality of service. In 2018 IEEE International Black Sea Conference on Communications and Networking (BlackSeaCom) (pp. 1-5). IEEE.

[14] Romanov, O. I., Hordashnyk, Y. S., & Dong, T. T. (2017, September). Method for calculating the energy loss of a light signal in a telecommunication Li-Fi system. In 2017 international conference on information and telecommunication technologies and radio electronics (UkrMiCo) (pp. 1-7). IEEE.

[15] M. Skulysh, F. Shilov and A. Safaryan. " Investigation of the method of computing resources optimal choice for billing systems effectiveness." CONTROL, NAVIGATION AND COMMUNICATION SYSTEMS. ACADEMIC JOURNAL 3.49 (2018): 147-152. DOI: https://doi.org/10.26906/SUNZ.2018.3.147

[16] Globa, L. S., Ishchenko, I., Kurdecha, V., Zakharchuk, A., & Zvonarov, O. (2016, June). An approach to the Internet of Things system with nomadic units developing. In 2016 IEEE International Black Sea Conference on Communications and Networking (BlackSeaCom) (pp. 1-5). IEEE.